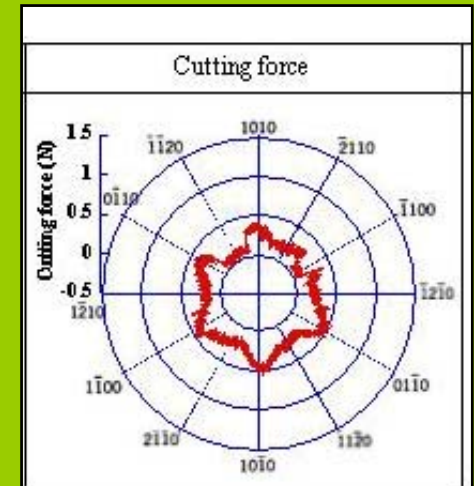


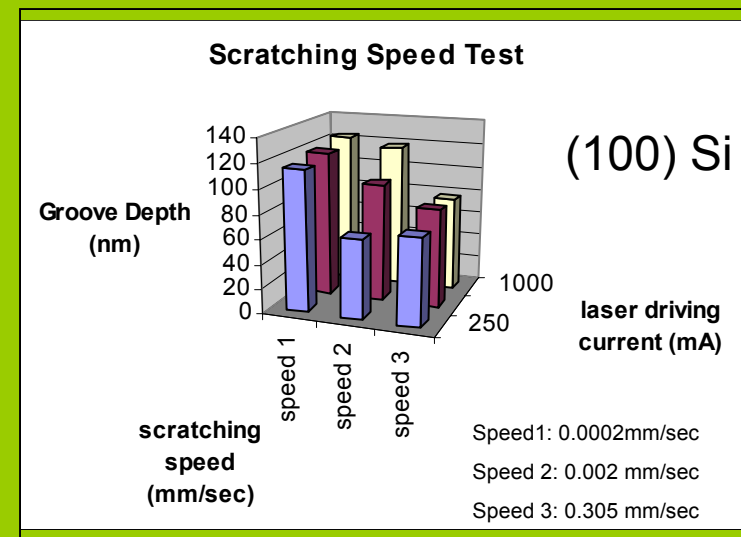
•Work this past year has included some additional studies on ductile behavior of single crystal SiC, which during single point diamond machining, clearly shows evidence of the 6 fold crystal symmetry. The higher cutting forces, in the figure to the right, indicate regions of ductile response, whereas the lower forces represent areas of brittle material behavior. The entire machined surface can be made to be either entirely ductile (preferred) or brittle through selection of process parameters such as dept of cut and rake angle.

SiC 6H Single Crystal  
6 fold crystal symmetry



100 nm depth of cut

•During this past year, it was determined that the metallic high pressure phase of semiconductors (Si) and ceramics (Si<sub>3</sub>N<sub>4</sub> & SiC) could be preferentially modified, without affecting the bulk substrate material, using electrical (resistance and inductance) and laser heating methods. The figure to the right shows that increased ductility (groove depth) can be achieved with reduced scratching speed (time) and higher laser current (power)



# FRG: High pressure phase transformations of semiconductors and ceramics

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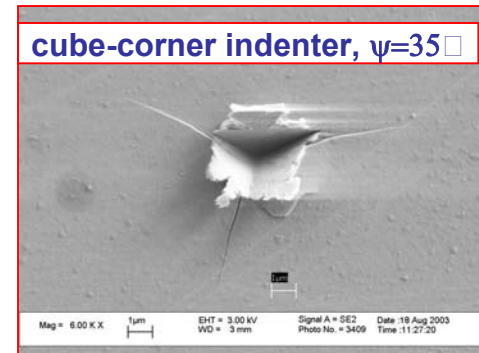
- Intellectual Merit: A number of significant new findings have been reported during this past year, these include:
  - Quantification of the effect of nanoindenter tip geometry on the high pressure phase transformation and ductile response of nominally hard-brittle semiconductors and ceramics
  - Crystallographic dependency of the ductile-brittle transition in single crystal SiC (6H).
  - Preferentially electrical and laser heating, and thermal softening, of the metallic high pressure phase, at the nano to micro scale.
  - Further documentation of the high-pressure induced phase transformations in ceramics, during nanoindentation, scratching and machining processes.
  - Success with modeling the plastic deformation of the high pressure phases of ceramics, via a pressure sensitive (Drucker-Prager) constitutive material model.
- Broader Impacts: Each year our FRG grant we host a workshop to bring together national and international experts working in this field. Two workshops have been conducted (2003 and 2004) at UNC Charlotte and NCSU (Raleigh). A third workshop is scheduled for UT-Knoxville in 2005.



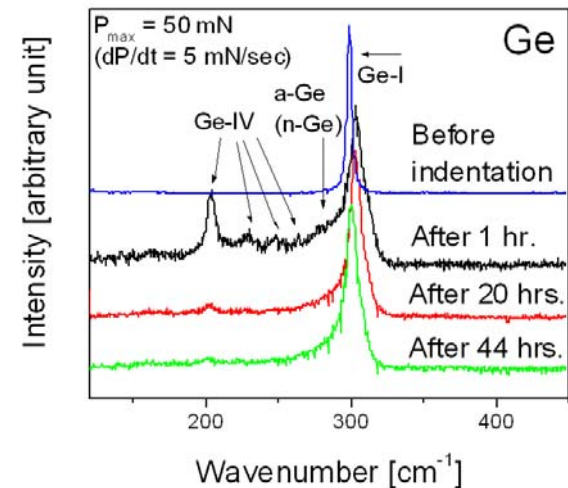
# High Pressure Phase Transformations of Silicon, Germanium, and Silicon Nitride

DMR-0203552

Experimental studies revealed for the first time that there can be extrusion of ductile material from around nanoindentation hardness impressions in germanium, just as in silicon. Extrusion had not been previously observed because it occurs only for very sharp indenters and not the Berkovich or spherical indenters used in most work. Micro-Raman spectroscopy showed that the transformed phases are crystalline Ge IV (bc8 structure) and amorphous Ge, but these revert to Ge I after only a few hours at room temperature. These observations help to explain why Ge can be precision machined in single point diamond turning operations even though its transformation behavior was heretofore thought to be quite different from Si.



First observation of ductile extrusion in Ge



Raman spectrum showing non-equilibrium phases